

## BOTTOM, STRANGE MESONS ( $B = \pm 1$ , $S = \mp 1$ )

$$B_s^0 = s\bar{b}, \bar{B}_s^0 = \bar{s}b, \text{ similarly for } B_s^* \text{'s}$$

**$B_s^0$**

$$I(J^P) = 0(0^-)$$

$I$ ,  $J$ ,  $P$  need confirmation. Quantum numbers shown are quark-model predictions.

Mass  $m_{B_s^0} = 5366.88 \pm 0.17$  MeV

$m_{B_s^0} - m_B = 87.40 \pm 0.18$  MeV

Mean life  $\tau = (1.510 \pm 0.004) \times 10^{-12}$  s

$$c\tau = 452.7 \mu\text{m}$$

$$\Delta\Gamma_{B_s^0} = \Gamma_{B_{sL}^0} - \Gamma_{B_{sH}^0} = (0.090 \pm 0.005) \times 10^{12} \text{ s}^{-1}$$

### $B_s^0$ - $\bar{B}_s^0$ mixing parameters

$$\begin{aligned} \Delta m_{B_s^0} &= m_{B_{sH}^0} - m_{B_{sL}^0} = (17.757 \pm 0.021) \times 10^{12} \hbar \text{ s}^{-1} \\ &= (1.1688 \pm 0.0014) \times 10^{-8} \text{ MeV} \end{aligned}$$

$$x_s = \Delta m_{B_s^0} / \Gamma_{B_s^0} = 26.81 \pm 0.08$$

$$\chi_s = 0.499308 \pm 0.000004$$

### CP violation parameters in $B_s^0$

$$\text{Re}(\epsilon_{B_s^0}) / (1 + |\epsilon_{B_s^0}|^2) = (-0.15 \pm 0.70) \times 10^{-3}$$

$$C_{KK}(B_s^0 \rightarrow K^+ K^-) = 0.14 \pm 0.11$$

$$S_{KK}(B_s^0 \rightarrow K^+ K^-) = 0.30 \pm 0.13$$

$$r_B(B_s^0 \rightarrow D_s^\mp K^\pm) = 0.37^{+0.10}_{-0.09}$$

$$\delta_B(B_s^0 \rightarrow D_s^\pm K^\mp) = (358 \pm 14)^\circ$$

$$CP \text{ Violation phase } \beta_s = (1.1 \pm 1.6) \times 10^{-2} \text{ rad}$$

$$|\lambda| (B_s^0 \rightarrow J/\psi(1S)\phi) = 0.964 \pm 0.020$$

$$|\lambda| = 1.002 \pm 0.017$$

$$A, CP \text{ violation parameter} = -0.75 \pm 0.12$$

$$C, CP \text{ violation parameter} = 0.19 \pm 0.06$$

$$S, CP \text{ violation parameter} = 0.17 \pm 0.06$$

$$A_{CP}^L(B_s \rightarrow J/\psi \bar{K}^*(892)^0) = -0.05 \pm 0.06$$

$$A_{CP}^{\parallel}(B_s \rightarrow J/\psi \bar{K}^*(892)^0) = 0.17 \pm 0.15$$

$$A_{CP}^{\perp}(B_s \rightarrow J/\psi \bar{K}^*(892)^0) = -0.05 \pm 0.10$$

$$A_{CP}(B_s \rightarrow \pi^+ K^-) = 0.221 \pm 0.015$$

$$A_{CP}(B_s^0 \rightarrow [K^+ K^-]_D \bar{K}^*(892)^0) = -0.04 \pm 0.07$$

$$\begin{aligned}
A_{CP}(B_s^0 \rightarrow [\pi^+ K^-]_D K^*(892)^0) &= -0.01 \pm 0.04 \\
A_{CP}(B_s^0 \rightarrow [\pi^+ \pi^-]_D K^*(892)^0) &= 0.06 \pm 0.13 \\
A^\Delta(B_s \rightarrow \phi \gamma) &= -1.0 \pm 0.5 \\
\Delta a_\perp &< 1.2 \times 10^{-12} \text{ GeV, CL = 95\%} \\
\Delta a_\parallel &= (-0.9 \pm 1.5) \times 10^{-14} \text{ GeV} \\
\Delta a_X &= (1.0 \pm 2.2) \times 10^{-14} \text{ GeV} \\
\Delta a_Y &= (-3.8 \pm 2.2) \times 10^{-14} \text{ GeV} \\
\text{Re}(\xi) &= -0.022 \pm 0.033 \\
\text{Im}(\xi) &= 0.004 \pm 0.011
\end{aligned}$$

These branching fractions all scale with  $B(\bar{B} \rightarrow B_s^0)$ .

The branching fraction  $B(B_s^0 \rightarrow D_s^- \ell^+ \nu_\ell \text{anything})$  is not a pure measurement since the measured product branching fraction  $B(\bar{B} \rightarrow B_s^0) \times B(B_s^0 \rightarrow D_s^- \ell^+ \nu_\ell \text{anything})$  was used to determine  $B(\bar{B} \rightarrow B_s^0)$ , as described in the note on “ $B^0$ - $\bar{B}^0$  Mixing”

For inclusive branching fractions, e.g.,  $B \rightarrow D^\pm \text{anything}$ , the values usually are multiplicities, not branching fractions. They can be greater than one.

$B_s^0$ DECAY MODES	Fraction ( $\Gamma_i/\Gamma$ )	Scale factor/ Confidence level	$p$ (MeV/c)
$D_s^- \text{anything}$	(93 $\pm$ 25) %	—	—
$\ell \nu_\ell X$	( 9.6 $\pm$ 0.8 ) %	—	—
$e^+ \nu X^-$	( 9.1 $\pm$ 0.8 ) %	—	—
$\mu^+ \nu X^-$	(10.2 $\pm$ 1.0 ) %	—	—
$D_s^- \ell^+ \nu_\ell \text{anything}$	[a] ( 8.1 $\pm$ 1.3 ) %	—	—
$D_s^{*-} \ell^+ \nu_\ell \text{anything}$	( 5.4 $\pm$ 1.1 ) %	—	—
$D_{s1}(2536)^- \mu^+ \nu_\mu, D_{s1}^- \rightarrow D^{*-} K_S^0$	( 2.6 $\pm$ 0.7 ) $\times 10^{-3}$	—	—
$D_{s1}(2536)^- X \mu^+ \nu, D_{s1}^- \rightarrow \bar{D}^0 K^+$	( 4.4 $\pm$ 1.3 ) $\times 10^{-3}$	—	—
$D_{s2}(2573)^- X \mu^+ \nu, D_{s2}^- \rightarrow \bar{D}^0 K^+$	( 2.7 $\pm$ 1.0 ) $\times 10^{-3}$	—	—
$D_s^- \pi^+$	( 3.00 $\pm$ 0.23 ) $\times 10^{-3}$	2320	—
$D_s^- \rho^+$	( 6.9 $\pm$ 1.4 ) $\times 10^{-3}$	2249	—
$D_s^- \pi^+ \pi^+ \pi^-$	( 6.1 $\pm$ 1.0 ) $\times 10^{-3}$	2301	—
$D_{s1}(2536)^- \pi^+, D_{s1}^- \rightarrow D_s^- \pi^+ \pi^-$	( 2.5 $\pm$ 0.8 ) $\times 10^{-5}$	—	—
$D_s^\mp K^\pm$	( 2.27 $\pm$ 0.19 ) $\times 10^{-4}$	2293	—
$D_s^- K^+ \pi^+ \pi^-$	( 3.2 $\pm$ 0.6 ) $\times 10^{-4}$	2249	—
$D_s^+ D_s^-$	( 4.4 $\pm$ 0.5 ) $\times 10^{-3}$	1824	—

$D_s^- D^+$	$( 2.8 \pm 0.5 ) \times 10^{-4}$	1875
$D^+ D^-$	$( 2.2 \pm 0.6 ) \times 10^{-4}$	1925
$D^0 \bar{D}^0$	$( 1.9 \pm 0.5 ) \times 10^{-4}$	1930
$D_s^{*-} \pi^+$	$( 2.0 \pm 0.5 ) \times 10^{-3}$	2265
$D_s^{*\mp} K^\pm$	$( 1.33 \pm 0.35 ) \times 10^{-4}$	—
$D_s^{*-} \rho^+$	$( 9.6 \pm 2.1 ) \times 10^{-3}$	2191
$D_s^{*+} D_s^- + D_s^{*-} D_s^+$	$( 1.37 \pm 0.16 ) \%$	1742
$D_s^{*+} D_s^{*-}$	$( 1.44 \pm 0.20 ) \%$	S=1.1 1655
$D_s^{(*)+} D_s^{(*)-}$	$( 4.5 \pm 1.4 ) \%$	—
$\bar{D}^{*0} \bar{K}^0$	$( 2.8 \pm 1.1 ) \times 10^{-4}$	2278
$\bar{D}^0 \bar{K}^0$	$( 4.3 \pm 0.9 ) \times 10^{-4}$	2330
$\bar{D}^0 K^- \pi^+$	$( 1.04 \pm 0.13 ) \times 10^{-3}$	2312
$\bar{D}^0 \bar{K}^*(892)^0$	$( 4.4 \pm 0.6 ) \times 10^{-4}$	2264
$\bar{D}^0 \bar{K}^*(1410)$	$( 3.9 \pm 3.5 ) \times 10^{-4}$	2117
$\bar{D}^0 \bar{K}_0^*(1430)$	$( 3.0 \pm 0.7 ) \times 10^{-4}$	2113
$\bar{D}^0 \bar{K}_2^*(1430)$	$( 1.1 \pm 0.4 ) \times 10^{-4}$	2113
$\bar{D}^0 \bar{K}^*(1680)$	$< 7.8 \times 10^{-5}$	CL=90% 1997
$\bar{D}^0 \bar{K}_0^*(1950)$	$< 1.1 \times 10^{-4}$	CL=90% 1890
$\bar{D}^0 \bar{K}_3^*(1780)$	$< 2.6 \times 10^{-5}$	CL=90% 1971
$\bar{D}^0 \bar{K}_4^*(2045)$	$< 3.1 \times 10^{-5}$	CL=90% 1837
$\bar{D}^0 K^- \pi^+ (\text{non-resonant})$	$( 2.1 \pm 0.8 ) \times 10^{-4}$	2312
$D_{s2}^*(2573)^- \pi^+, D_{s2}^* \rightarrow \bar{D}^0 K^-$	$( 2.6 \pm 0.4 ) \times 10^{-4}$	—
$D_{s1}^*(2700)^- \pi^+, D_{s1}^* \rightarrow \bar{D}^0 K^-$	$( 1.6 \pm 0.8 ) \times 10^{-5}$	—
$D_{s1}^*(2860)^- \pi^+, D_{s1}^* \rightarrow \bar{D}^0 K^-$	$( 5 \pm 4 ) \times 10^{-5}$	—
$D_{s3}^*(2860)^- \pi^+, D_{s3}^* \rightarrow \bar{D}^0 K^-$	$( 2.2 \pm 0.6 ) \times 10^{-5}$	—
$\bar{D}^0 K^+ K^-$	$( 5.5 \pm 0.8 ) \times 10^{-5}$	2243
$\bar{D}^0 f_0(980)$	$< 3.1 \times 10^{-6}$	CL=90% 2242
$\bar{D}^0 \phi$	$( 3.0 \pm 0.5 ) \times 10^{-5}$	2235
$\bar{D}^{*0} \phi$	$( 3.7 \pm 0.6 ) \times 10^{-5}$	2178
$D^{*\mp} \pi^\pm$	$< 6.1 \times 10^{-6}$	CL=90% —
$\eta_c \phi$	$( 5.0 \pm 0.9 ) \times 10^{-4}$	1663
$\eta_c \pi^+ \pi^-$	$( 1.8 \pm 0.7 ) \times 10^{-4}$	1840
$J/\psi(1S) \phi$	$( 1.08 \pm 0.08 ) \times 10^{-3}$	1588
$J/\psi(1S) \phi \phi$	$( 1.24 \pm 0.17 ) \times 10^{-5}$	764
$J/\psi(1S) \pi^0$	$< 1.2 \times 10^{-3}$	CL=90% 1787
$J/\psi(1S) \eta$	$( 4.0 \pm 0.7 ) \times 10^{-4}$	S=1.4 1733
$J/\psi(1S) K_S^0$	$( 1.88 \pm 0.15 ) \times 10^{-5}$	1743
$J/\psi(1S) \bar{K}^*(892)^0$	$( 4.1 \pm 0.4 ) \times 10^{-5}$	1637

$J/\psi(1S)\eta'$	$( 3.3 \pm 0.4 ) \times 10^{-4}$		1612
$J/\psi(1S)\pi^+\pi^-$	$( 2.09 \pm 0.23 ) \times 10^{-4}$	S=1.3	1775
$J/\psi(1S)f_0(500), f_0 \rightarrow \pi^+\pi^-$	$< 4 \times 10^{-6}$	CL=90%	-
$J/\psi(1S)\rho, \rho \rightarrow \pi^+\pi^-$	$< 4 \times 10^{-6}$	CL=90%	-
$J/\psi(1S)f_0(980), f_0 \rightarrow \pi^+\pi^-$	$( 1.28 \pm 0.18 ) \times 10^{-4}$	S=1.7	-
$J/\psi(1S)f_2(1270), f_2 \rightarrow \pi^+\pi^-$	$( 1.1 \pm 0.4 ) \times 10^{-6}$		-
$J/\psi(1S)f_2(1270)_0, f_2 \rightarrow \pi^+\pi^-$	$( 7.5 \pm 1.8 ) \times 10^{-7}$		-
$J/\psi(1S)f_2(1270)_{  }, f_2 \rightarrow \pi^+\pi^-$	$( 1.09 \pm 0.34 ) \times 10^{-6}$		-
$J/\psi(1S)f_2(1270)_\perp, f_2 \rightarrow \pi^+\pi^-$	$( 1.3 \pm 0.8 ) \times 10^{-6}$		-
$J/\psi(1S)f_0(1370), f_0 \rightarrow \pi^+\pi^-$	$( 4.5 \pm 0.7 ) \times 10^{-5}$		-
$J/\psi(1S)f_0(1500), f_0 \rightarrow \pi^+\pi^-$	$( 2.11 \pm 0.40 ) \times 10^{-5}$		-
$J/\psi(1S)f'_2(1525)_0, f'_2 \rightarrow \pi^+\pi^-$	$( 1.07 \pm 0.24 ) \times 10^{-6}$		-
$J/\psi(1S)f'_2(1525)_{  }, f'_2 \rightarrow \pi^+\pi^-$	$( 1.3 \pm 2.7 ) \times 10^{-7}$		-
$J/\psi(1S)f'_2(1525)_\perp, f'_2 \rightarrow \pi^+\pi^-$	$( 5 \pm 4 ) \times 10^{-7}$		-
$J/\psi(1S)f_0(1790), f_0 \rightarrow \pi^+\pi^-$	$( 5.0 \pm 11.0 ) \times 10^{-6}$		-
$J/\psi(1S)\pi^+\pi^- (\text{nonresonant})$	$( 1.8 \pm 1.1 ) \times 10^{-5}$		1775
$J/\psi(1S)\bar{K}^0\pi^+\pi^-$	$< 4.4 \times 10^{-5}$	CL=90%	1675
$J/\psi(1S)K^+K^-$	$( 7.9 \pm 0.7 ) \times 10^{-4}$		1601
$J/\psi(1S)K^0K^-\pi^+ + \text{c.c.}$	$( 9.3 \pm 1.3 ) \times 10^{-4}$		1538
$J/\psi(1S)\bar{K}^0K^+K^-$	$< 1.2 \times 10^{-5}$	CL=90%	1333
$J/\psi(1S)f'_2(1525)$	$( 2.6 \pm 0.6 ) \times 10^{-4}$		1304
$J/\psi(1S)p\bar{p}$	$< 4.8 \times 10^{-6}$	CL=90%	982
$J/\psi(1S)\gamma$	$< 7.3 \times 10^{-6}$	CL=90%	1790
$J/\psi(1S)\pi^+\pi^-\pi^+\pi^-$	$( 7.8 \pm 1.0 ) \times 10^{-5}$		1731
$J/\psi(1S)f_1(1285)$	$( 7.0 \pm 1.4 ) \times 10^{-5}$		1460
$\psi(2S)\eta$	$( 3.3 \pm 0.9 ) \times 10^{-4}$		1338
$\psi(2S)\eta'$	$( 1.29 \pm 0.35 ) \times 10^{-4}$		1158
$\psi(2S)\pi^+\pi^-$	$( 7.1 \pm 1.3 ) \times 10^{-5}$		1397
$\psi(2S)\phi$	$( 5.4 \pm 0.6 ) \times 10^{-4}$		1120
$\psi(2S)K^-\pi^+$	$( 3.1 \pm 0.4 ) \times 10^{-5}$		1310
$\psi(2S)\bar{K}^*(892)^0$	$( 3.3 \pm 0.5 ) \times 10^{-5}$		1196
$\chi_{c1}\phi$	$( 2.04 \pm 0.30 ) \times 10^{-4}$		1274

$\pi^+ \pi^-$		$( 6.8 \pm 0.8 ) \times 10^{-7}$		2680
$\pi^0 \pi^0$		$< 2.1 \times 10^{-4}$	CL=90%	2680
$\eta \pi^0$		$< 1.0 \times 10^{-3}$	CL=90%	2654
$\eta \eta$		$< 1.5 \times 10^{-3}$	CL=90%	2627
$\rho^0 \rho^0$		$< 3.20 \times 10^{-4}$	CL=90%	2569
$\eta' \eta'$		$( 3.3 \pm 0.7 ) \times 10^{-5}$		2507
$\eta' \phi$		$< 8.2 \times 10^{-7}$	CL=90%	2495
$\phi f_0(980), f_0(980) \rightarrow \pi^+ \pi^-$		$( 1.12 \pm 0.21 ) \times 10^{-6}$		—
$\phi f_2(1270), f_2(1270) \rightarrow \pi^+ \pi^-$		$( 6.1 \pm 1.8 ) \times 10^{-7}$		—
$\phi \rho^0$		$( 2.7 \pm 0.8 ) \times 10^{-7}$		2526
$\phi \pi^+ \pi^-$		$( 3.5 \pm 0.5 ) \times 10^{-6}$		2579
$\phi \phi$		$( 1.87 \pm 0.15 ) \times 10^{-5}$		2482
$\phi \phi \phi$		$( 2.2 \pm 0.7 ) \times 10^{-6}$		2165
$\pi^+ K^-$		$( 5.6 \pm 0.6 ) \times 10^{-6}$		2659
$K^+ K^-$		$( 2.54 \pm 0.17 ) \times 10^{-5}$		2638
$K^0 \bar{K}^0$		$( 2.0 \pm 0.6 ) \times 10^{-5}$		2637
$K^0 \pi^+ \pi^-$		$( 9.4 \pm 2.1 ) \times 10^{-6}$		2653
$K^0 K^\pm \pi^\mp$		$( 8.4 \pm 0.9 ) \times 10^{-5}$		2622
$K^*(892)^- \pi^+$		$( 2.9 \pm 1.1 ) \times 10^{-6}$		2607
$K^*(892)^\pm K^\mp$		$( 1.12 \pm 0.22 ) \times 10^{-5}$		2585
$K_S^0 \bar{K}^*(892)^0 + \text{c.c.}$		$( 1.6 \pm 0.4 ) \times 10^{-5}$		2585
$K^0 \bar{K}^+ K^-$		$( 1.3 \pm 0.6 ) \times 10^{-6}$		2568
$\bar{K}^*(892)^0 \rho^0$		$< 7.67 \times 10^{-4}$	CL=90%	2550
$\bar{K}^*(892)^0 K^*(892)^0$		$( 1.11 \pm 0.27 ) \times 10^{-5}$		2531
$\phi K^*(892)^0$		$( 1.14 \pm 0.30 ) \times 10^{-6}$		2507
$p \bar{p}$		$< 1.5 \times 10^{-8}$	CL=90%	2514
$p \bar{p} K^+ K^-$		$( 4.5 \pm 0.5 ) \times 10^{-6}$		2231
$p \bar{p} K^+ \pi^-$		$( 1.39 \pm 0.26 ) \times 10^{-6}$		2355
$p \bar{p} \pi^+ \pi^-$		$( 4.3 \pm 2.0 ) \times 10^{-7}$		2454
$p \bar{\Lambda} K^- + \text{c.c.}$		$( 5.5 \pm 1.0 ) \times 10^{-6}$		2358
$\Lambda_c^- \Lambda \pi^+$		$( 3.6 \pm 1.6 ) \times 10^{-4}$		—
$\Lambda_c^- \Lambda_c^+$		$< 8.0 \times 10^{-5}$	CL=95%	—

**Lepton Family number (*LF*) violating modes or  
 $\Delta B = 1$  weak neutral current (*B1*) modes**

$\gamma \gamma$	<i>B1</i>	$< 3.1 \times 10^{-6}$	CL=90%	2683
$\phi \gamma$	<i>B1</i>	$( 3.4 \pm 0.4 ) \times 10^{-5}$		2587
$\mu^+ \mu^-$	<i>B1</i>	$( 3.0 \pm 0.4 ) \times 10^{-9}$		2681
$e^+ e^-$	<i>B1</i>	$< 2.8 \times 10^{-7}$	CL=90%	2683
$\tau^+ \tau^-$	<i>B1</i>	$< 6.8 \times 10^{-3}$	CL=95%	2011
$\mu^+ \mu^- \mu^+ \mu^-$	<i>B1</i>	$< 2.5 \times 10^{-9}$	CL=95%	2673
$S P, S \rightarrow \mu^+ \mu^-, P \rightarrow \mu^+ \mu^-$	<i>B1</i>	[b] $< 2.2 \times 10^{-9}$	CL=95%	—

$\phi(1020)\mu^+\mu^-$	<i>B1</i>	$(8.2 \pm 1.2) \times 10^{-7}$	2582
$K^*(892)^0\mu^+\mu^-$		$(2.9 \pm 1.1) \times 10^{-8}$	2605
$\pi^+\pi^-\mu^+\mu^-$	<i>B1</i>	$(8.4 \pm 1.7) \times 10^{-8}$	2670
$\phi\nu\bar{\nu}$	<i>B1</i>	$< 5.4 \times 10^{-3}$	CL=90% 2587
$e^\pm\mu^\mp$	<i>LF</i>	$[c] < 5.4 \times 10^{-9}$	CL=90% 2682

**$B_s^*$**

$$I(J^P) = 0(1^-)$$

*I, J, P* need confirmation. Quantum numbers shown are quark-model predictions.

$$\text{Mass } m = 5415.4^{+1.8}_{-1.5} \text{ MeV } (S = 2.9)$$

$$m_{B_s^*} - m_{B_s} = 48.6^{+1.8}_{-1.5} \text{ MeV } (S = 2.9)$$

<b><math>B_s^*</math> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	<i>p</i> (MeV/c)
$B_s\gamma$	seen	48

**$B_{s1}(5830)^0$**

$$I(J^P) = 0(1^+)$$

*I, J, P* need confirmation.

$$\text{Mass } m = 5828.70 \pm 0.20 \text{ MeV}$$

$$m_{B_{s1}^0} - m_{B^{*+}} = 504.00 \pm 0.17 \text{ MeV}$$

$$\text{Full width } \Gamma = 0.5 \pm 0.4 \text{ MeV}$$

<b><math>B_{s1}(5830)^0</math> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	<i>p</i> (MeV/c)
$B^{*+}K^-$	seen	97

**$B_{s2}^*(5840)^0$**

$$I(J^P) = 0(2^+)$$

*I, J, P* need confirmation.

$$\text{Mass } m = 5839.85 \pm 0.12 \text{ MeV}$$

$$m_{B_{s2}^{*0}} - m_{B^+} = 560.53 \pm 0.14 \text{ MeV}$$

$$\text{Full width } \Gamma = 1.49 \pm 0.27 \text{ MeV}$$

<b><math>B_{s2}^*(5840)^0</math> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	<i>p</i> (MeV/c)
$B^+K^-$	<b>DEFINED AS 1</b>	252
$B^{*+}K^-$	$0.093 \pm 0.018$	141
$B^0 K_S^0$	$0.43 \pm 0.11$	245
$B^{*0} K_S^0$	$0.04 \pm 0.04$	—

## NOTES

- [a] Not a pure measurement. See note at head of  $B_s^0$  Decay Modes.
- [b] Here  $S$  and  $P$  are the hypothetical scalar and pseudoscalar particles with masses of  $2.5 \text{ GeV}/c^2$  and  $214.3 \text{ MeV}/c^2$ , respectively.
- [c] The value is for the sum of the charge states or particle/antiparticle states indicated.